CLAIMS

1. A heat exchanger for delivery of heat transfer fluid to a process heat transfer surface which is in contact with a process fluid wherein the heat transfer surface fluid is delivered in at least five heat transfer conduits each having a cross sectional area for the flow path of less than 2000 square millimetres wherein the linear velocity of the heat transfer fluid through the heat transfer conduits is from 0.5 to 20 $m.s^{-1}$ and adapted so that the temperature of the heat transfer fluid changes by at least 1°C when they system is operating at design heat load.

2. A heat exchange according to Claim 1 in which the time taken for the heat transfer fluid to pass through the heat exchanger as measured in seconds is not greater than twice length of the heat transfer surface when said length is measured in metres.

3. A heat exchanger according to claim 1 or Claim 2 in which the conduits have a cross sectional area for the flow path of less than 180 square millimetres.

4. A heat exchanger according to any of the preceding Claims wherein the cross sectional area of the flow path for the individual heat transfer conduits is less than 80 square millimetres.

5. A heat exchanger according to any of the preceding Claims where the heat transfer fluid is delivered in 5 or more separate heat transfer fluid conduits where the total inventory of gas, liquid or solid to be heated or cooled within the device is less than 1000 litres.

6. A heat exchanger according to any of the preceding claims where the heat transfer fluid is delivered in 3 or more separate heat transfer fluid conduits per 1000 litres of gas, liquid or solid to be heated where the total inventory of said gas, liquid or solid within the heat transfer device is greater than 1000 litres.

7. A heat exchanger according to any of the preceding claims wherein the temperature of the heat transfer fluid passing through the heat exchanger changes by at least 5°C when the system is operating at full design heating load.

8. A heat exchanger according to any of the preceding claims wherein the flow condition of the heat transfer fluid is laminar.

9. A heat exchanger according to any of the preceding claims wherein the linear velocity of the heat transfer fluid through the heat transfer conduit is between 0.5 and 5 $m.s^{-1}$ for liquid cooled systems when the heat exchanger is operating at full design load and between 2 and 20 $m.s^{-1}$ for gas cooled systems when the heat exchanger is operating at full design load.

10. A heat exchanger according to any of the preceding claims wherein the shape and size of the flow path for the heat transfer fluid is adapted to increase the area of the heat transfer surface between the heat transfer fluid and said conduit.

11. A heat exchanger according to any of the preceding claims wherein inserts are fitted within the conduit carrying the heat transfer fluid.

12. A heat exchanger according to any of the preceding claims wherein the internal surface of the conduit is profiled by means of knurling, striations, dimpling or other surface profiling.

13. A heat exchanger according to any of the preceding claims wherein baffling is provided within the heat transfer conduits.

14. A heat exchanger according to any of the preceding claims whereby the heat transfer fluid flows within independent conduits which are not in direct contact with the gas, liquid or solid which is being heated or cooled and that the heat transfer fluid conduit is bonded, fused, glued, brazed, welded or soldered to the surface which serves as the containment barrier for the gas, liquid or solid which is being heated or cooled.

15. A heat exchanger according to any of claims 1 to 13 wherein the heat transfer fluid conduit or conduits is held to the surface which serves as the containment barrier for the gas, liquid or solid which is being heated or cooled by means of clamps, springs, wires, natural shape of the conduit or some other form mechanical fixing.

16. A heat exchanger according to claim 15 wherein a layer of a soft, thermally conductive material such as conductive grease, fluid, conductive wool, fibrous conductive mat or a mixture thereof is provided between the transfer fluid conduit and the surface which serves as the containment barrier for the gas, liquid or solid which is being heated or cooled.

17. A heat exchanger according to any of the preceding claims wherein the heat transfer fluid conduits are mounted in tiers so that two or more conduits may deliver heat to the same area of heat transfer surface.

18. A heat exchanger according to any of the preceding claims wherein the conduit for the heat transfer fluid is mounted on an expansion plate to permit independent movement of the heat transfer conduit in relation to the containment barrier for the gas, liquid or solid which is being heated or cooled.

19. A heat exchanger according any of the preceding claims where the conduits carrying the heat transfer fluid and/or expansion plates are fabricated in copper, copper alloy or any other material with good thermal conductive properties.

20. A heat exchanger according to any of the preceding claims whereby the heat transfer conduits pass through the body of the gas, liquid or solid which is being heated or cooled.

21. A heat exchanger according to any of the preceding claims including a valve or flow restrictor on each conduit for carrying heat transfer fluid.

22. A heat exchanger according to any of the preceding claims which uses a variable area heat transfer surface.

23. A heat exchanger according to any of the preceding claims comprising a reaction calorimeter.

24. A heat exchanger according to any of the preceding claims wherein the volumetric capacity of solid, liquid or gas to be heated or cooled within the heat exchanger is greater than 1000 litres.

25. A heat exchanger according to any of the preceding claims in which the residence time of the heat transfer fluid is less than 6 seconds.

26. The use of a heat exchanger according to any of the preceding claims temperature for control in batch process equipment such as stirred tanks, batch reactors, crystallisers, dryers, fermenters, cell growth vessels, filters, mixers or mills.

27. The use of a heat exchanger according to any of the claims 1 to 25 for temperature control in continuous equipment such as reactors, mixers, mills, extruders, dryers, compressors, internal combustion engines or air conditioning systems.

28. The use according to claim 26 or claim 27 in the manufacture of chemicals, foods or pharmaceutical products in quantities of greater than 1000 kilograms per year.

29. A heat transfer system for the transfer of heat between a process fluid and a heat transfer fluid across a heat transfer surface comprising a heat transfer conduit for passage of the heat transfer fluid attached to an expansion plate said expansion plate being in contact with the heat transfer surface said expansion plate enabling independent movement of the heat transfer conduit and the heat transfer surface.

30. A heat transfer system according to claim 29 wherein the heat transfer surface which is in contact with a process fluid wherein the heat transfer fluid is delivered in at least five heat transfer conduits each having a cross sectional area for the flow path of less than 2000 square millimetres wherein the linear velocity of the heat transfer fluid through the heat transfer conduits is from 0.5 to 20 $m.s^{-1}$ and adapted so that the temperature of the heat transfer fluid changes by at least 1°C when they system is operating at full design load.

31. A heat exchange according to Claim 30 in which the time taken for the heat transfer fluid to pass through the heat exchanger as measured in seconds is not greater than twice the length of the heat transfer surface when said length is measured in metres

32. A heat transfer system according to any of claims 29 or claim 31 wherein the heat transfer fluid is delivered in at least five heat transfer conduits each having a cross sectional area for the flow path of less than 180 square millimetres.

33. A heat transfer system according to any of claims 29 to 32 wherein the heat transfer fluid is delivered in five or more separate heat transfer fluid conduits where the total inventory of gas, liquid or solid to be heated or cooled within the device is less than 1000 litres.

34. A heat transfer system according to any of claims 29 to 33 wherein the heat transfer fluid is delivered in three or more separate heat transfer fluid conduits per 1000 litres of gas, liquid or solid to be heated where the total inventory of said gas, liquid or solid within the heat transfer device is greater than 1000 litres.

35. A heat transfer system according to any of claims 29 to 34 where the cross sectional area of the flow path for the individual heat transfer conduits is less than 180 square millimetres.

36. A heat transfer system according to any claims 28 to 34 wherein the thermal design is such that the temperature of the heat transfer fluid passing through the heat exchanger changes by at least 5°C when the system is operating at full design load.

37. A heat transfer system according to any of the claims 29 to 36 wherein the flow condition of the heat transfer fluid is laminar.

38. A heat transfer system according to any of claims 29 to 37 whereby the linear velocity of the heat transfer fluid through the heat transfer element is between 0.5 and 5 $m.s^{-1}$ for liquid cooled systems when the heat exchanger is operating at full design load and between 2 and 20 $m.s^{-1}$ for gas cooled systems when the heat exchanger is operating at full design load.

39. A heat transfer system according to any of claims 29 to 38 whereby the shape and size of the flow path for the heat transfer fluid is modified in order to increase the area of the heat transfer surface between the heat transfer fluid and said conduit.

40. A heat transfer system according to any of claims 29 to 39 wherein inserts are fitted within the conduit carrying the heat transfer fluid.

41. A heat transfer system according to any of claims 29 to 40 wherein the internal surface of the conduit is profiled by means of knurling, striations, dimpling or some other surface profiling.

42. A heat transfer system according to any of claims 29 to 41 wherein baffling in used within the heat transfer conduits.

43. A heat transfer system according to any of claims 29 to 42 whereby the heat transfer fluid flows within independent conduits which are not in direct contact with the gas, liquid or solid which is being heated or cooled and that the heat transfer fluid conduit is bonded, fused, glued, brazed, welded or soldered to the surface which serves as the containment barrier for the gas, liquid or solid which is being heated or cooled.

44. A heat transfer system according to any of claims 29 to 42 where the heat transfer fluid flows within independent conduits which are not in direct contact with the gas, liquid or solid which is being heated or cooled and that the heat transfer fluid conduit is held to the surface which serves as the containment barrier for the gas, liquid or solid which is being heated or cooled by means of clamps, springs, wires, natural shape of the conduit or some other form mechanical fixing.

45. A heat transfer system according to claim 44 wherein the gap between the heat transfer fluid conduit and the surface which serves as the containment barrier for the gas, liquid or solid which is being heated or cooled is filled by means of a soft, thermally conductive material such as conductive grease, fluid, conductive wool, fibrous conductive mat or a composite of several of these materials.

46. A heat transfer system according to any of claims 29 to 45 wherein the heat transfer fluid conduits are mounted in tiers so that two or more conduits may deliver heat to the same area of surface which contains the gas, liquid or solid to be heated or cooled.

47. A heat transfer system according to any of claims 29 to 46 wherein the conduits carrying the heat transfer fluid and/or the expansion plates are fabricated in copper, copper alloy or any other material with good thermal conductive properties.

48. A heat transfer system according to any of claims 29 to 47 which includes a valve or flow restrictor on each conduit for carrying heat transfer fluid.

49. A heat transfer system according to any of claims 29 to 48 which uses a variable area heat transfer surface as the parameter for temperature control.

50. A heat transfer system according to any of claims 29 to 49 which is a reaction calorimeter.

51. A heat transfer system according to any of claims 29 to 50 wherein the volumetric capacity of solid, liquid or gas to be heated or cooled within the heat exchanger is greater than 1000 litres.

52. A heat transfer system according to any of claims 29 to 51 in which the residence time of the heat transfer fluid is less than 6 seconds.

53. The use of a heat transfer system according to any of claims 29 to 52 to control the temperature of batch process equipment such as stirred tanks, batch reactors, crystallisers, dryers, fermenters, cell growth vessels, filters, mixers or mills.

54. The use of a heat transfer system according to any of claims 29 to 52 to control the temperature of continuous equipment such as reactors, mixers, mills, extruders, dryers, compressors, internal combustion engines or air conditioning systems.

55. The use according to claim 53 or claim 54 for manufacturing chemicals, foods or pharmaceutical products in quantities of greater than 1000 kilograms per year.

56. The use of a predetermined t_{si}-t_{so} of a heat transfer process fluid to be employed in a heat exchanger for the design of the heat exchanger so as to reduce the hold up volume of heat transfer fluid within the heat exchanger to the minimum acceptable volume.

57. The use of a predetermined linear velocity of the heat transfer fluid to be employed in a heat exchanger for the design of the heat exchanger so as to reduce the hold up volume of heat transfer fluid within the heat exchanger to the minimum acceptable volume.

58. The use according to claim 56 or claim 57 such that the length of the hydraulic flow path parallel to the heat transfer surface (L) is not be more than 10 times the overall internal width (W) of the hydraulic flow path where more than one conduit lies in parallel to the heat transfer surface.